REPORTS OF OBSERVATORIES.[1]

CHAMBERLIN OBSERVATORY, DENVER, COLORADO.

During the year 1907 Mr. D. SHELTON SWAN and the director of the observatory made observations of comets and of the planet *Eros*.

H. A. HOWE, *Director*.

INTERNATIONAL LATITUDE OBSERVATORY, UKIAH, CALIFORNIA.

Regular observation for the variation of latitude was continued throughout 1907, according to the programme assigned by the International Geodetic Association.

Doctor S. D. TOWNLEY was succeeded in charge September 1st by the writer. A comparison of over five hundred of the 835 separate determinations of the latitude made between June 13th and August 30th, about half by each observer, showed practically no difference of personal equation. The probable error of a single determination was found to be about $0''.10$ for each observer.

The weather was in general favorable, till the later months of the year, when there was an abnormal prevalence of clouds. The longest interval without observations was twelve nights, December 1st to 12th, due to almost continuous cloudy weather; there were two intervals of seven days, due to unfavorable weather, in the first quarter of the year.

The following table gives a summary of the observations for the variation of latitude. The columns contain, respectively, the number of determinations made each month, the number of nights on which observations were made, the number of complete nights (sixteen determinations), and the greatest interval in each month during which no measures were obtained:—

[1] Arranged alphabetically according to name.

1907.	Pairs.	Nights.	Nights.	Nights.
January	152	11	7	6
February	158	12	8	7
March	147	12	7	7
April	209	15	10	4
May	180	15	10	5
June	231	17	13	4
July	356	24	20	2
August	303	21	13	2
September	178	13	5	3
October	146	12	2	5
November	167	12	5	6
December	68	5	1	12
Totals	2,295	169	101	
Means	191	14	8+	5+

Seven determinations of the constants of the zenith telescope, well distributed in time, indicate very satisfactory stability throughout the year.

JAMES D. MADDRILL,
Astronomer-in-Charge.

LICK OBSERVATORY, MOUNT HAMILTON, CALIFORNIA.

(The report will be printed in the next number of the *Publications.*)

LOWELL OBSERVATORY, FLAGSTAFF, ARIZONA.

The work of the observatory for the past year includes: (1) Visual and photographic observations of the planets *Venus, Mars, Jupiter,* and *Saturn;* (2) The visual and photographic observations on *Mars* made by the South American expedition; (3) Spectrographic work on the planets with especial reference to the lower red end of the spectra for investigations on atmospheric absorption effects; studies in detail of the spectrum of *Mars* and of different parts of the disk of *Jupiter;* (4) Radial velocity determinations of a selected list of stars; (5) Charting of star-fields along the ecliptic with the Brashear doublet, and the discovery of eleven new asteroids, the determination of their positions as well as the positions of a large number of known asteroids; (6) Micrometric measures of double stars; (7) Many laboratory visual experiments with reference to testing the validity of certain visual observations

on the planets; (8) Photographic experiments with regard to applications in planetary photography and the photography of spectra; (9) Work on the improvement of methods and equipment for use in planetary photography. A more detailed account of the above follows.

Visual observations on *Mars* were begun here on March 22d and continued until January, 1908. The opposition of the planet just past was one of the so-called favorable ones. The great southern declination of the planet, however, rendered it difficult for most observatories in the northern hemisphere. The more southern latitude of Flagstaff was here to its advantage. In spite of the low altitude of the planet, the outcome of the observations there, both visual and photographic, were very successful. The two most important results were (1) the observations on the two polar caps at their simultaneous maximum and minimum states respectively, their subsequent careers, and the addition to the knowledge of them in consequence; and, (2) the detection of a canal system connecting with the south polar cap analogous to that already detected for the northern. This was an especially telling contribution, as it confirmed the theory of the office and behavior of the canals previously advanced here.

At the suggestion of Professor TODD, the Director decided to send an expedition to South America in his charge, and Mr. E. C. SLIPHER was detailed by the Director for the *Mars* work. Planetary camera, amplifying lenses, color filters, and plates were made for him, the duplicates of those used in the work at Flagstaff. The party sailed from New York on May 11th, and arrived at Iquique, Chili, June 14th. The observing station selected, Alanza, was about sixty miles inland southeast from Iquique, in the desert Tarapaca, at an altitude of about four thousand feet. The excellent quality of both photographs and drawings shows that the expedition was very fortunate in finding at the first trial a locality with conditions so favorable for their work. Much credit is due to all the members of the expedition for the part they contributed to making the undertaking a success, and especially must great praise be given to Mr. SLIPHER for his part in the work. All the *Mars* observations were made by him, and the excellent series of drawings and photographs he returned with testified to his ability and industry in carrying out the programme of work planned.

Mention must also be made of the efficient assistance rendered him by Mr. A. G. ILSE, who was kindly detailed by the Alvan Clark & Sons Corporation to be the mechanician of the expedition.

The photography of *Mars* was begun at Flagstaff on June 3d and continued until September 2d. Photographs were made by Mr. LAMPLAND and the Director, and in all a little over five thousand images were made. At the South American station, photographs were made by Mr. SLIPHER from June 24th until August 1st. Actual count since his return shows that he had made over 13,300 exposures. The South American photographs are, on the whole, superior, though a large per cent of the images of both series have excellent definition. In 1907 the larger and brighter disk of the planet, more efficient camera equipment devised by Mr. LAMPLAND, and the value of experience in the work, all contributed to obtaining better photographs than those made during the opposition of 1905. The length of time covered by the present series and the uniformly good quality of the images make them of great value, not only as a corroboration of the drawings, but also for study independent of the visual results. The photographs show an amount of delicate detail that is truly remarkable, and their importance and value in the advancement of Martian study can best be fully appreciated by any one who has spent much time and care in charting visually the difficult detail of the planet. Detail that taxed vision to the utmost, especially markings in regions lacking in or having slight differences of contrast, could sometimes be seen with ease in the negatives made at the same time. These results bring out well the efficiency of the photographic plate, with suitable exposure and development, in registering delicate detail and small variations in contrast. Generally the photographs bring out the detail in the dark regions better, compared with the appearance of the planet visually, than in the light regions, and the negative here seems to be superior to the eye in detecting small differences of contrast. Of course, for form, fineness, or linearity, the eye is first. Some idea of the delicacy of the detail photographed may be gathered from the fact that the twin canals Gihon and Euphrates were shown double in many of the images, made at different dates, of both the South American and the Flagstaff photographs.

The series of measures by Mr. LAMPLAND and the Director, for the determination of the position of the axis of *Mars* and the eccentricity of the south polar cap, have been reduced and entirely confirm the lesser obliquity of the Martian ecliptic, found from the earlier Flagstaff measures, 1901-1905. (See *Lowell Observatory Bulletin*, Nos. 9 and 24.) This shows that the change in the obliquity suggested by the writer, and now incorporated in the ephemeris of the "British Nautical Almanac," was in the right direction.

Observations on *Venus* were made by the Director during the summer months, confirming his detection of the markings upon it in 1896-7 and 1903, and have been continued by Mr. E. C. SLIPHER since November.

Jupiter was observed during April and May. A good series of drawings and a number of photographs were made. The wisps crossing the equatorial belt, so well shown in the drawings of Mr. SCRIVEN BOLTON, of England, were easily seen, and also confirmed by photographs.

Observations were made on *Saturn* in June and from the first of November until January. A little before sunrise on June 19th, a new phenomenon was detected here in the ring system. The most conspicuous feature of the disk at the time was the dark band, the shadow of the rings, which then belted the planet's equator. The shadow, far from being dark, was only moderately dusky, and furthermore presented, when first looked at, a curious tripartite appearance. On more careful scrutiny its lack of uniformity proved to be due to a narrow black line that threaded it medially throughout its length, the black core being perhaps one fourth as wide as the less dense background upon which it stood. At the same time, the rings themselves could with attention be made out as the finest knife-edges of light cutting the blue of space on either side of the planet's disk. The planet was not looked at again until October 31st, other work occupying the observatory in the meantime. In November, however, it was critically studied. The dusky band was evident, as in June, and the black line made core to it, as before. This black medial line was by no means even; it both undulated slightly and showed irregularities of outline, one black bead in especial being noticeable upon it about half way from the planet's center to its (the

planet's) eastern limb. (November 13, 7^h, M. S. T.) The line also seemed not quite central in the belt, but a little nearer its northern edge. In November the rings were easily seen, although, as before, only the edge of their plane was presented to the eye. But in addition to the general line of their light, agglomerations were plainly discernible on them. A number of measures of the agglomerations and the core of the shadow-band were made in November and December. During the last part of December the agglomerations were too faint for measurement, and were last seen by Mr. LAMPLAND on December 31st. The rings were glimpsed by him on January 3d and 4th, but were then so faint that he was unable to see if irregularities were still present. Unfavorable conditions prevented observations until January 7th, when the rings were easily seen and found to be perfectly continuous. An investigation by the writer, explaining the core of the shadow-band and the agglomerations in the ansæ of the rings, has been published in detail elsewhere. A brief statement of the results of this study may be of interest here. The investigation brings out the interesting fact that the particles composing the ring-system cannot all be situated in one plane—that the rings are not flat rings but tores, rings after the manner of anchor-rings, encircling the planet. This out-of-planeness of the particles is easily seen, applying the methods of celestial mechanics, to be a consequence of the perturbing influence of the nearer satellites and the mutual impacts of the particles of the rings. In support of this view, we find that micrometric measures place the agglomerations where we should expect to find them from theoretical considerations. The black core of the shadow-band leads to a like conclusion: that in the black core we are looking at such parts of the ring-system as are practically plane, chiefly ring *A*, and in the dusky shadow about it through particles, situated above and below that plane, lying in the other rings.

The spectrographic work done during the year has been confined principally to studies of the red end of the spectra of the planets, and the radial velocity determinations of a selected list of stars. With greatly improved red-sensitive plates, perfected by his extensive experiments with sensitizing dyes, Mr. SLIPHER has been able to photograph many hitherto unknown absorption bands and lines in the spectra of the major planets.

The lower red end of the spectra of the other planets and many stars are almost as interesting as those of the major planets. Of the new bands discovered in the spectra of the major planets, the strongest is found near λ 7200. This band in *Jupiter* and *Saturn* is far stronger than the characteristic one at λ 6190. A series of plates of the spectra of *Mars* and the Moon, photographed at equal altitudes, and under favorable conditions, on nights selected on account of their advantageous meteorological state, shows this band to be reinforced in the spectrum of *Mars*. The band λ 7200 coincides in position and appearance with the "a" group of the telluric spectrum which ROWLAND and JEWELL found to be due to water vapor. The *D* band is likewise broadened relatively with *Mars* spectra, indicating enforcement of the water-vapor lines there.

A study has been made of the spectrum from different parts of the disk of *Jupiter*, revealing interesting differences.

The results of these spectrographic studies will be published in the near future.

A good deal of attention has been given to the problem of planetary photography, with a view to devising more efficient methods and equipment for that work. The planetary camera was rebuilt, according to designs by Mr. LAMPLAND, during January and February, by WM. GAERTNER & Co., of Chicago. In planetary photography, with a visual refractor, good color screens form a very important part of the equipment, and every effort has been made to obtain the best ones that could be made. Both solid (stained film of gelatine between plates of optical glass) and liquid (glass cell with plane-parallel walls containing the absorbing solution) filters have been used. Mr. R. J. WALLACE made three more solid filters, and adjusted the absorbing solution for two liquid-filter cells. The optical parts for the liquid filters were made by Mr. O. L. PETITDIDIER, and were figured accurately plane. The absorption values of two of the solid filters and of one of the solutions for the liquid filters were adjusted by Mr. WALLACE according to specifications based on investigations by the writer. Mr. SLIPHER'S remarkable success in his experiments in sensitizing plates, with comparatively even sensitiveness for a long range of the spectrum extending far into the red, suggested that his plates might be used with good results in planetary photography in

connection with a suitable color-screen, by which more perfect monochromatization relatively to the amount of light forming the image might be attained. Tests of the plates in the photography of the planet brought out that they lacked the quality of delicate gradation so important in this work. Later tests of the new filter, using Cramer's isochromatic plates, showed that it gave definition superior to the filters formerly used, though requiring a little longer exposure to give the same density of image. It proved indeed to have been previously made for use with these plates, though not for planetary photography. The investigation on the filters, giving a statement of the principles involved and the results of the experiments, will be found in *Lowell Observatory Bulletin,* No. 31.

Experiments were made with commercial photographic lenses (ZEISS and COOKE) for amplifying lenses in the planetary photography, but these were not found to perform as well as the new negative lens made by Mr. LUNDIN, of the Alvan Clark & Sons Corporation.

In the laboratory visual experiments performed, in connection with investigations on *Mars,* efforts have been made to carry them out under conditions as nearly like those found in actual observational work as possible. The 24-inch, 6-inch, and 4-inch telescopes, with different magnifications, have been used in the experiments. By varying the different factors, optical systems, apertures, and magnifications, and "seeing" (atmospheric disturbances) conditions existing in observing, work can be approximated quite satisfactorily. For instance, the effect of atmospheric disturbances can be obtained by selecting certain moments for the observations, or by varying the length of the air-path, or the magnification. At the same time, one can of course vary the dimensions of the objects observed until they have the required angular dimensions. The optical systems and general conditions being about the same as in actual observing work, conclusions can more safely be drawn from the experimental work.

Other additions to the equipment than those already mentioned were, a new device for illumination of the field and improved electric illumination of the micrometer of the 24-inch telescope, and a large observing chair of the same pattern as the one used at the Ladd Observatory.

PERCIVAL LOWELL, *Director.*

NAVAL OBSERVATORY, MARE ISLAND, CALIFORNIA.

During the past year the work of this observatory has been about the same as in past years. The number of chronometers rated and issued to ships has, however, somewhat increased, owing to the increased naval activities in the Pacific. The time service has continued as heretofore, and wireless messages have been installed for giving the time to the fleet at Magdalena Bay, Lower California. These messages cannot be sent great distances by day, and at present are delivered on Mondays and Thursdays of each week, at 9 o'clock at night. This service has proved satisfactory. In some cases messages have been delivered to ships near Honolulu, at a distance of fifteen hundred miles from the transmitting station.

In addition to the routine work of the observatory as regularly carried on, the officer in charge has continued his researches on "The Cause of Earthquakes and Mountain Formation." Three papers on this subject have been published in the *Proceedings* of the American Philosophical Society at Philadelphia. The new theory, that these disturbances are due to the secular leakage of the ocean bottoms, may now be regarded as proved. The subject thus opened up, however, is still so unexplored that a fourth paper is to be added to those already published, in order to render the theory more complete.

Recently the officer in charge has taken up a general revision of the orbits of double stars. Ten orbits, mostly of new pairs, have recently been communicated to the Royal Astronomical Society in London. The earthquake researches, which proved so fruitful of discovery in the domain of the physics of the Earth, were the natural outcome of the previous work on the internal constitution of the Sun and planets carried out here in 1904 and 1905, and published in the *Astronomische Nachrichten*. When the great earthquake occurred it was felt to be a public duty to seek out the cause of such disturbances, in the hope of ascertaining the relative safety of California. This region is now shown to be much less endangered than most regions about the Pacific Ocean.

T. J. J. SEE,
Professor of Mathematics, U. S. Navy,
in charge of the Observatory.

SOLAR OBSERVATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON, MT. WILSON, CALIFORNIA.

The investigations in progress during the past year include:

1. Daily photography of the Sun with the photoheliograph.
2. Daily photography of the Sun with the spectroheliograph.
3. Photography of the spectra of sun-spots.
4. Photographic comparisons of the spectra of various parts of the Sun's disk.
5. Spectrographic investigations of the solar rotation.
6. Laboratory investigations.
7. Pyrheliometric observations.

Direct photographs of the Sun have been made daily with the Snow telescope, by Mr. ELLERMAN or Mr. OLMSTED. These negatives are used mainly for comparison with spectroheliograph plates.

The daily series of photographs made by Mr. ELLERMAN or Mr. OLMSTED, with the 5-foot spectroheliograph and Snow telescope, comprises negatives made in the early morning and late afternoon, with the lines of calcium, hydrogen, and iron. The hydrogen line regularly employed is $H\delta$. We have recently discovered, however, that the $H\alpha$ line gives results differing very decidedly from those obtained with $H\delta$. The high sensitiveness for red light imparted to photographic plates by bathing them in a three-dye solution, devised by Mr. WALLACE, of the Yerkes Observatory, permits excellent photographs to be made with the $H\alpha$ line, in spite of the comparatively low dispersion in the red of the 5-foot spectroheliograph, and the consequent necessity of using a very narrow camera slit. Hereafter $H\alpha$ plates will be taken regularly, since the bright flocculi which they bring out are sometimes, if not invariably, absent from the $H\delta$ plates. There also seem to be interesting differences in the forms of the dark flocculi shown by the two lines. These results have only just been obtained, and it has not yet been possible to ascertain the causes which produce the interesting and striking differences revealed by the photographs.

The 30-foot spectroheliograph of the tower telescope is under construction and should be in use within a few months.

Some experiments have been made, however, with the 30-foot Littrow spectrograph of the tower telescope used as a spectroheliograph. The 12-inch object-glass, of sixty feet focal length, of this telescope, is mounted in a carriage and connected with an electric motor in such a way that it can be moved at a uniform rate in an east-and-west direction. This causes the image of the Sun, formed in a house at the base of the tower, to move across the collimator slit of the spectrograph. Most of the work has been done in the second-order spectrum of a 4-inch plane grating, which is not nearly large enough for the full aperture (six inches) of the spectrograph, but is nevertheless better suited for this purpose than any other grating in our possession. The spectroheliograph attachment consists of a plate-carrier movable on steel balls across two adjustable slits. This apparatus is mounted on the spectrograph in the position usually occupied by the plate-holder employed for photographing spectra. The two slits are made to coincide with any two lines of the spectrum, and the photographic plate is moved over them at the same rate as the solar image—by means of the same motor. In this way monochromatic images of limited regions of the Sun can be photographed simultaneously with two of the Fraunhofer lines. With this apparatus the peculiarities of the $H\alpha$ lines were discovered. Experiments are now in progress with other dark lines. A special attempt will be made with this instrument, and with the permanent 30-foot spectroheliograph, to determine whether anomalous dispersion phenomena are exhibited by the flocculi.

The photographic study of the spectra of sun-spots, which was mentioned in the last annual report, has been continued and extended through the advantages afforded by the new tower telescope. The negatives of spot spectra made with the 18-foot Littrow spectrograph and Snow telescope have been used for a preliminary photographic map of the spot spectrum, extending from λ 4600 to λ 7200. The map consists of twenty-six strips, each including one hundred Ångströms, and is provided with a solar spectrum for comparison purposes and an approximate scale to aid in the identification of spot lines. At the recent Paris meeting of the International Union for Coöperation in Solar Research this map was adopted for the use of the coöperating observers. Each visual observer has

selected a certain limited region of the spot spectrum, in which he compares the lines, as seen at the telescope, with those recorded on the map. In this way any changes in the relative intensities of the lines, if such occur, can be readily detected. Copies of the map have been placed in the hands of all observers who are taking part in this work of the Solar Union.

A preliminary catalogue of the lines affected in sun-spots is being prepared by Mr. ADAMS and myself, with the assistance of Miss BURWELL, of the Computing Division. The first installment of this catalogue, prepared by Mr. ADAMS, covers the region λ 4000 to λ 4500, and contains about 875 lines. The publication of the second portion of the catalogue, covering the region from λ 4500 to λ 5000, has been delayed by the fact that the photographs of spot spectra, made with the 30-foot spectrograph and the tower telescope, show many more lines than our previous photographs. These plates are therefore being used in preference to the earlier ones in preparing the catalogue. They will also serve to give a definitive map of the spot spectrum on a scale of 4^{mm} to an Ångström. Special apparatus for enlarging and widening the spectra for this map is now under construction and will soon be ready for use.

The hypothesis that the relative intensities of the spot lines are due to reduced temperature has received further confirmation during the year, especially through the identification in the spot spectrum of many bands due to compounds. This work is referred to below in connection with other laboratory investigations.

A photographic study of the spectra of various parts of the Sun, made by Mr. ADAMS and myself, has shown that marked differences distinguish the spectrum of the center from that of points very near the limb. The Fraunhofer lines not only undergo changes of intensity, similar to those observed in the case of sun-spots, but they are also shifted in many instances from their normal positions. Since the lines of the cyanogen flutings are not shifted, and since the relative displacements of various metallic lines correspond fairly well with their displacements produced by pressure in the laboratory, it seems probable that the changes in line positions are due to an increase of effective pressure near the limb. Such a conclusion would be in agreement with the views of HALM. How-

ever, a continuation of the solar work, which already covers a large range of the spectrum, and a number of laboratory investigations will be required to settle the question definitely. It seems probable that the observed phenomena, which include several not mentioned above, such as the marked reduction in intensity of winged lines at the limb, are due to a combination of several causes, of which increased pressure may be one.

Mr. ADAMS's spectrographic investigation of the solar rotation, which was begun with the Snow telescope and 18-foot Littrow spectrograph, have been continued with the tower telescope and 30-foot spectrograph. The following table contains the results published in *Contributions from the Solar Observatory,* No. 20:—

ϕ	Weight.	v km.	ξ	Period, Days.
0°.2	21	2.078	14°.75	24.39
7 .7	15	2.023	14 .50	24.83
15 .0	23	1.957	14 .39	25.01
22 .7	13	1.808	13 .92	25.86
29 .7	24	1.673	13 .68	26.32
37 .7	15	1.461	13 .11	27.46
44 .7	23	1.279	12 .77	28.19
52 .7	18	1.055	12 .35	29.15
59 .6	24	0.864	12 .13	29.68
65 .7	20	0.696	11 .99	30.02
74 .9	33	0.434	11 .85	30.38
80 .4	11	0.277	11 .84	30.40

The more important conclusions derived from this investigation may be summarized as follows:—

(1) The period of rotation agrees closely with that of DUNÉR as far as latitude 50°. In higher latitudes it is considerably shorter. It does not agree with either of the determinations of HALM, but coincides well with their mean.

(2) Different lines give slightly different rotation periods. Of the elements investigated carbon and lanthanum give the longest periods. At the equator this difference amounts to about 0°.1 in the daily angular motion.

(3) No appreciable change in the rotation period has been found during the fourteen months covered by the observations.

(4) The photographic method gives results for individual lines of slightly higher accuracy than the visual, if we may judge from a comparison of the probable errors. The greatest advantage it possesses, however, is the opportunity it affords for the inclusion of many more lines than would be possible with visual measures.

The extension of this work to include the hydrogen lines has led to the important results summarized in the following table:—

ϕ	$v+v-$	ξ	Period, Days.
—0°.1	2.21^{km}	15°.7	22.9
9 .3	2.15	15 .5	23.2
14 .8	2.10	15 .4	23.4
22 .7	2.03	15 .6	23.1
29 .7	1.87	15 .3	23.5
44 .5	1.55	15 .4	23.4
59 .3	1.12	15 .6	23.1
73 .5	0.67	16 .7	21.6

From these results it appears that the hydrogen whose speed is measured with the spectrograph does not follow the same law of rotation as the spots. The daily motion of the hydrogen is much greater than that of the spots at the equator, and has about the same values in high and in low latitudes. Similar results obtained from the motions of the hydrogen flocculi are described below. The spectrographic work is being continued, and other lines will be included for measurement.

As the development of our solar investigations has been hampered by the meager information available on the spectra of the elements under various conditions of temperature, pressure, etc., an important extension of our laboratory work has been rendered necessary. In order that we may be in a position to make a suitable study of anomalous dispersion phenomena, and to continue the investigation described in my last report on the cause of the characteristic phenomena of sun-spot spectra, a powerful electric furnace was required. Other apparatus, demanding much heavier electric current than could easily be generated on Mt. Wilson, was also essential.

For this reason it was decided to build a small laboratory in Pasadena, where unlimited current can be obtained from the Edison Electric Company at moderate cost. This laboratory is now completed, and Dr. ARTHUR S. KING, formerly of the University of California, has been placed in charge of it.

Prior to the construction of the new laboratory practically all of the physical work was done on Mt. Wilson. Dr. OLMSTED'S investigations in this department during the year included an attempt to identify unknown bands in sun-spot spectra and a photographic investigation of the relation between the nature of the discharge of an electric arc and the relative intensities of its spectral lines. Some of the bands of titanium oxide were identified by Mr. ADAMS last year in our photographs of spot spectra, and subsequently Professor FOWLER found certain other bands in our map of the spot spectrum to be due to magnesium hydride. To these Mr. OLMSTED has added some bands observed in a calcium arc burning in an atmosphere of hydrogen. He has also made, with the 30-foot spectrograph of the tower telescope, a series of photographs covering the whole visible spectrum of titanium oxide. These plates are crowded with thousands of lines, many of which have not yet been identified in the spots.

The duties of the Smithsonian Astrophysical Observatory in Washington prevented the continuation of the Smithsonian Expedition's work on Mt. Wilson during the summer of 1907. At Mr. ABBOT'S request, however, a pyrheliometer was used by Mr. OLMSTED on many days during the year, for the purpose of determining the solar constant, on the assumption that the correction derived from the Smithsonian Expedition's observations in 1905-1906 can be applied to these results. This assumption is presumably valid, for it appears from Mr. ABBOT'S discussion of the bolometric results for 1906 that they can be duplicated from pyrheliometric and relative-humidity observations, with an average deviation for a single observation of 1.5 per cent.

The results of the important work done on Mt. Wilson, under the direction of Mr. ABBOT, in 1905 and 1906, have been published in Volume II of the *Annals of the Smithsonian Astrophysical Observatory*. This work will be continued here during the summer of 1908.

Professor JULIUS, of the University of Utrecht, spent several weeks on Mt. Wilson last summer, for the purpose of carrying on certain investigations on the phenomena of anomalous dispersion. These were made with an electric furnace, the 5-foot spectroheliograph being employed to photograph the phenomena produced in a tube of sodium vapor by slight changes of density caused by local cooling. These phenomena resemble, in some respects, those of the solar flocculi, which Professor JULIUS ascribes to anomalous ray-curving in the Sun. A symmetrical illumination, similar to that employed in these experiments, may be secured near a sun-spot, from the edge of which photospheric light reaches us after transmission through calcium and other vapors where density gradients doubtless exist. It should be possible to learn whether the H_1 flocculi are the effects of anomalous dispersion by photographing a spot group with the camera-slit set on H_1. If photographs of the same group are taken simultaneously with the same spectroheliograph, having a second camera-slit set on the continuous spectrum, the distance between the edges of two spots should, in general, differ in the photographs. If any differences exist, they should increase as the camera-slit is set nearer H_1. Furthermore, photographs made with the camera-slit set on opposite sides of H_1, should give differences in the form and appearance of the flocculi. It is hoped that these tests can soon be made with the tower telescope and 30-foot spectroheliograph. Many other investigations will be made with the hope of determining conclusively what part, if any, anomalous dispersion plays in solar physics.

The work of the Computing Division, under the direction of Mr. ADAMS, has progressed very satisfactorily during the year. Miss WARE has devoted all of her time to the measurement of the heliographic positions of flocculi with the heliomicrometer, for the purpose of determining the solar rotation. The measurement of the calcium (H_2) flocculi is not yet completed, but the preliminary results given by 1680 flocculi on fifty-one plates are shown in the following table:—

Latitude.	Calcium (H) No. Points.	Flocculi ξ	Hydrogen ($H\delta$) No. Points.	Flocculi ξ
0° ± 5°	232	14.5	91	14.3
5 ± 10	262	14.3	77	14.4
10 ± 15	317	14.3	95	14.6
15 ± 20	326	14.2	73	14.5
20 ± 25	259	14.2	71	14.7
25 ± 30	153	14.0	65	14.7
30 ± 35	99	13.8	33	14.9
35 ± 40	26	14.0	23	14.6
40 ± 45	6	13.2	19	14.4

In this table are also given a preliminary determination of the mean daily motions of the dark hydrogen ($H\delta$) flocculi, as derived from the measurement of 547 flocculi on twenty different plates. On account of the large proper motions and rapid changes of form of the hydrogen flocculi, their mean daily motions cannot be determined with as great precision as is possible in the case of calcium. However, it will be seen that the results in the table give no evidence of a systematic variation of the rotation with the latitude, such as is observed in the case of sun-spots, and also in that of the calcium flocculi. Since, as has already been pointed out, Mr. ADAMS's spectrographic work also shows that hydrogen moves at approximately the same angular velocity in all heliographic latitudes, it is evident that the well-known law of equatorial acceleration does not hold for all classes of solar phenomena. The speed of the hydrogen measured spectrographically is considerably greater than that of the flocculi. Many more measures, however, will be required to give the motion of the flocculi with sufficient precision for satisfactory comparisons. It now remains to be determined whether their comparatively slow motion is due to the fact that the hydrogen in the flocculi rises from lower levels and retains the smaller velocities prevalent there, or, as seems more likely, that the hydrogen lines whose displacements are observed at the Sun's limb are due mainly to absorption at a level above that of the dark $H\delta$ flocculi. The recent work on the $H\alpha$ flocculi, referred to at the opening of this report, is not unlikely to throw some light on this question.

Miss SMITH is now concluding the reduction of a large number of measures of the areas of the calcium flocculi lying in squares 10° on a side within an area extending 40° in latitude and 40° in longitude from the Sun's center. These results are expected to give a valuable measure of the total solar activity, and to indicate its fluctuations in different parts of the Sun.

Miss LASBY has devoted most of her time to the measurement of photographs taken by Mr. ADAMS for the spectrographic determination of the solar rotation. She has also measured a number of photographs of spectra corresponding to the center of the Sun and to points near the limb.

Miss BURWELL has been engaged in the study of photographs of spot spectra, measuring the positions of unknown lines, and estimating the intensities of the lines which differ from those of the solar spectrum.

Miss WICKHAM, who has recently joined the Computing Division, is occupied with the measurement of metallic spectra.

The work of the Construction Division, which has been continued under the superintendence of Mr. RITCHEY, has included the optical and mechanical work on the 60-inch reflector; the construction of two mirrors and many of the mechanical parts of the new tower telescope, and its erection upon Mt. Wilson; the completion of the Mt. Wilson Road, and the transportation of materials to the summit of the mountain; the erection of the steel building and dome for the 60-inch reflector; the construction of the Hooker Building and the new spectroscopic laboratory in Pasadena; and miscellaneous work on minor instruments.

All of the optical work for the 60-inch reflector, except the final figuring of the two small convex mirrors, has been completed by Mr. RITCHEY. The mounting is now being assembled for the last time, preparatory to sending it up the mountain. It is hoped that this can be done early in June, soon after the mountain road has been put in repair. This road was completed in May, 1907, and more than 150 tons of steel, for the building and dome of the 60-inch reflector, were hauled over it before the beginning of the present rainy season. The road has not been greatly damaged by the recent storms, and can soon be put in condition for the heavy demands of

next summer's work. The skeleton of the steel building and dome has been erected on Mt. Wilson, but the completion of the riveting and the work connected with the shutter, driving mechanism, observing platform, wind-screen, etc., cannot be completed for several months. It had been hoped that all of this work could be finished last year, but labor troubles and strikes at the Union Iron Works, and other unexpected difficulties, caused unforseen delays.

The new tower telescope erected last autumn has already been described in these *Publications*. It has proved to be an extremely satisfactory instrument, especially in combination with the 30-foot spectrograph. The excellent definition obtained with this telescope, and the fact that the mirrors are not distorted by sunlight, has already permitted several investigations to be made which could not be carried out with the Snow telescope.

Work on the 4.5-ton glass disk for the 100-inch reflector is still in progress at St. Gobain, France. Meanwhile, in view of Mr. HOOKER's desire that the necessary arrangements for grinding and figuring be made before the disk reaches us, a building has been erected for the optical work, and the large grinding machine is now approaching completion. In addition to a grinding room and testing hall, the new Hooker Building contains rooms for grinding and polishing tools, a fireproof storage vault for astrophysical negatives, and a series of computing offices. It thus forms a most valuable addition to our resources in Pasadena. Mr. RITCHEY is at work on preliminary designs for the 100-inch mounting, but no attempt will be made to complete these before the 60-inch mounting has been thoroughly tested.

GEORGE E. HALE, *Director*.

STUDENTS' OBSERVATORY, BERKELEY ASTRONOMICAL DEPARTMENT, UNIVERSITY OF CALIFORNIA.

During the past year, as heretofore, the chief work of the Berkeley Astronomical Department of the University of California has been in the line of instruction. The number of enrollments in the department and the demand for additional courses increases steadily from year to year. The number of students enrolled in astronomical courses for the current aca-

demic year now exceeds four hundred as against two hundred and sixteen in 1905-1906. The teaching force has been increased by the appointment of Mr. W. F. MEYER, a graduate of Drake University. The usual course of six lectures offered by the Lick Observatory staff in connection with the course in Modern Astronomy has proved a most instructive and profitable feature of the opportunities offered to the general student body. Eight graduate students, who are looking forward to the degree of Doctor of Philosophy, were enrolled in the Lick and Berkeley astronomical departments at the close of the year 1907.

The work of investigating the perturbations of the minor planets discovered by JAMES C. WATSON was continued during the past year as heretofore. It is now over six years since this investigation was undertaken in the department. No one not familiar with the details of this work can form an adequate idea of the theoretical and practical difficulties which have been encountered. The present condition of the Watson work is as follows:—

1. Tables are being printed of the following twelve planets:—

(93) *Minerva.*	(105) *Artemis.*	(139) *Juewa.*
(101) *Helena.*	(115) *Thyra.*	(161) *Athor.*
(103) *Hera.*	(128) *Nemesis.*	(174) *Phædra.*
(119) *Althæa.*	(133) *Cyrene.*	(179) *Klytæmnestra.*

2. The perturbations are developed, the observations collected, and the elements corrected for the following five planets:—

(94) *Aurora.*	(104) *Clymene.*	(150) *Nuwa.*
(100) *Hekate.*	(121) *Hermione.*	

A second correction of the elements is necessary. The principal perturbations of the second order may have to be computed for some of these planets.

3. The perturbations are developed for one planet:—

(79) *Eurynome.*

4. *Three* planets belong to the group ½, and special tables for this group have been computed after BOHLIN. A comparison of these tables with similar tables by VON ZEIPEL needs to be made before developing the perturbations. The original

programme for these planets may be changed by adopting the Gyldèn-Brendel-Kramer method. These planets are:—

(106) *Dione.* (168) *Sybilla.* (175) *Andromache.*

5. One planet, (132) *Æthra,* is lost. Computations are under way to decide its fate.

Total number of planets = 22.

Of the twelve planets for which the tables are completed and in press, comparison has been made of recent subsequent observations with the tables with eminently satisfactory results, except in the case of (115) *Thyra,* which was in opposition in May and for which observations have not as yet become known, although an ephemeris was published in *Lick Observatory Bulletin,* No. 114. The average interval which has elapsed between the last observation used in the correction of the elements and perturbations on which the tables are based has been from six to seven years. Some of these observations have been especially secured at the Lick Observatory and at the U. S. Naval Observatory for the purpose of testing the tables. The numerical part of the work will now be interrupted temporarily, mainly for the purpose of enabling Professor LEUSCHNER to prepare a definite programme for the completion of the tables of the remaining ten planets. At least one half of the computations necessary on these planets are completed. It is estimated that upon resumption of the computations the work of two computers for one year will be required for completing the Watson work inclusively of constructing the necessary tables. Among the practical difficulties encountered were those due to erroneous identifications of minor planets. Observers ought to realize that the opposition positions given in the *Jahrbuch* do not, in general, take account of the perturbations, which in some cases affect the geocentric positions by many degrees, and that not infrequently more than one planet occupies nearly the same position in the sky.

All other activities of the observatory referred to in former reports, such as seismological and meteorological observations and occasional astronomical observations, have also been continued during the past year, and minor contributions have been made to astronomical journals.

In connection with the work of the State Earthquake Investigation Commission, the Director has prepared a complete

catalogue of all after-shocks observed in California up to June 10, 1907. This catalogue is being printed by the Carnegie Institution in the forthcoming report of the California State Earthquake Commission.

In connection with the courses in theoretical astronomy, Professor CRAWFORD has published a number of comet orbits jointly with members of his classes. These are: Elliptic Elements and Ephemerides of Comet *h* 1906 (METCALF), *L. O. Bulletin,* No. 108; Elements and Ephemeris of Comet *a* 1907 (GIACOBINI), *L. O. Bulletin,* No. 111; Second Elements and Ephemeris of Comet *a* 1907 (GIACOBINI), *L. O. Bulletin,* No. 113; Elements and Ephemeris of Comet *c* 1907 (GIACOBINI), *L. O. Bulletin,* No. 116; Elements and Ephemeris of Comet *d* 1907 (DANIEL), *L. O. Bulletin,* No. 119; Elements and Ephemeris of Comet *e* 1907 (MELLISH), *L. O. Bulletin,* No. 121; Second Elements and Ephemeris of Comet *e* 1907 (MELLISH), *L. O. Bulletin,* No. 124.

A. O. LEUSCHNER, *Director.*

BERKELEY, CAL., April 3, 1908.